

THERMO GRAVIMETRIC ANALYSIS OF PHOENIX SP. FIBER

EMMANUAL. L & KARTHI. R. R

Assistant Professor, M.Kumarasamy College of Engineering, Karur, Tamilnadu, India

ABSTRACT

The natural Fiber composite offers unique properties compared to those of conventional synthetic Fiber Composites. Thermal analysis is a vital technique to understand the structural properties of Fiber and its composites. The thermal behavior of untreated and treated Phoenix sp. Fibers were studied by using Thermo -Gravimetric Analysis (TGA). Thermal analysis of Phoenix sp. Fiber is carried out by changing the concentration of chemical treatment. The chemically treated Phoenix sp. The natural Fibers treated with 15% NaOH have good thermal properties compared to other Fibers. Thermal stability seems greater for 15% NaOH treated Fiber followed by 5% NaOH treated Fiber, 10 % NaOH treated Fiber and untreated Fiber.

KEYWORDS: Phoenix sp. Fiber Thermogravimetric analysis ,Chemical treatment & Composites Thermal stability

Received: Feb 21, 2018; **Accepted:** Mar 04, 2018; **Published:** Mar 22, 2018; **Paper Id.:** IJMPERDAPR2018127

INTRODUCTION

Natural Fibers are exposed to different environmental conditions. Hence the study of thermal properties of natural Fiber becomes necessary to use in engineering applications. The artificial Fiber has twice the weight of natural Fibers, more costlier which causes damage to human beings and the energy for extraction is more compared to natural Fiber. Paul et al. (2008) studied the thermal degradation performance of untreated banana Fiber by means of TGA. The degradation of banana Fiber occurred mainly in two stages; the first one has occurred around 320°C and the second stage occurred around 450°C. TGA curve of Banana Fiber shows the weight loss before 100°C weight loss of 6% occurred due to the moisture content. In the first stage, around 55% of weight loss takes place in the temperature range of 230-330°C and the second stage of degradation take place at the temperature range of 330-440°C. Ticoalu et al. (2014) performed TGA test on gomuti Fiber. A 10–50 mg of finely chopped Fibers samples were placed in a small aluminum pan which was suspended in TA Instruments Q500 v6.1, where the gomuti Fibers are heated up to a higher temperature of 600°C in the N₂ atmosphere at the heating rate of 5°C/min. For Untreated sample, the weight loss of 4.1% occurred due to the release of moisture content is at 48.1°C (<100°C). The next weight loss takes place around 248.8°C (>200°C) which is due to the removal of waxy layers and hemicelluloses. The main weight loss occurred at the last stage that is at 324.8°C. At this stage sample, the weight is almost reduced by half (44.1%). The degradation of untreated gomuti Fiber starts at lower temperature 222.8°C.

Kabir et al. (2010) tested the untreated hemp Fiber samples in a thermogravimetric analyser. The Fiber samples of 6 to 10 mg were heated from 25 to 500°C in the helium medium at the constant heating rate of 10°C/min, where the three -step degradation was determined from the TGA curve. At 30-110°C. The main phase of degradation is happened because of the arrival of dampness content from the hemp Fiber. The significant second stage degradation happened at the temperature scope of 200-300°C, which was related to the degradation

of hemicelluloses and lignin from the fiber. The last stage of degradation occurred at the temperature range of 340–380°C which shows the degradation of α -cellulose from the Fiber. Haameem et al. (2016) conducted the TGA test using 0.471 mg of untreated Napier grass Fiber under the flow of 50 ml/min nitrogen at the heating rate of 20°C/min. At the temperatures of 30–700°C the author observed the thermal properties of the untreated Napier grass Fibers. From the TGA curve of untreated Napier grass Fiber, the first stage of weight loss was started above the 80°C which is due to the moisture evaporation which was said by Geethamma et al. (1998). The weight loss at 270°C is around 20% of its initial weight, indicates the thermal depolymerization of the hemicellulose and the last stage of weight loss occurred at 345°C. The Napier grass Fiber was completely degraded above 500°C. Ramzy et al. (2014) had studied the thermal behavior of NaOH treated sisal Fiber using TA Q5000 IR. The TGA test was done under the N₂ atmosphere at the heating rate of 10K/min with the temperature of 600°C. At 336.63°C, the first degradation peak starts to occur, followed by the second degradation peak, which occurred at 459.3°C. Lee et al. (2012) studied the thermal behavior of poly AESO/sisal Fiber composite by using TGA Q500, TA Instruments. 35 mg of poly AESO/sisal Fiber composite samples are analyzed from a room temperature to 600°C at the heating rate of 5°C /min. The first step of degradation in the composites was occurred around 250°C which relates to the degradation of the Fibers which was given by Beall and Eickner (1970), continued by a second step of degradation that occurred around 350°C, which is the random chain scission of poly AESO stated by Behera and Banthia (2008). The residual weight was about 10 wt.% of the poly AESO/sisal Fiber Composites.

Arthanarieswaran et al. (2016) performed the TGA test on untreated Acacia leucophloea Fiber-reinforced epoxy composites by using simultaneous thermal analyzer STA 449 F3 at the temperature of 30 to 1000°C. Nishitani et al. (2016) conducted the thermal analysis in TGA thermo plus EVO2 equipment. The 10mg hemp Fiber filled polyamide 1010 biomass composite sample is heated at the temperature of 40 to 400°C at the heating rate of 10°C/min. The first weight loss takes place between the temperature 80–200°C and the next weight loss occurred at 300°C. Zuhudi et al. (2014) had studied the thermal properties of 10–12 mg of bamboo glass hybrid polypropylene composites using a Perkin Elmer Thermogravimetric analyzer from the temperature 10–600°C at a heating rate of 10°C /min under the air flow. In the composite sample at 250°C, a small weight loss was identified, which occurred generally due to the presence of water content in the composite samples. The bamboo glass hybrid polypropylene composites were thermally stable at 275°C. The TGA curve of bamboo glass hybrid polypropylene composite showed significant weight loss after 275°C approximately between the temperature ranges of 250–450°C. The major weight loss of the bamboo glass hybrid polypropylene composites has occurred at 400°C. The glass Fibers in composite remains as a residue hence the complete degradation of the bamboo glass hybrid polypropylene composites doesn't take place at this stage.

Seki et al. (2012) determined the thermal stability of 10 mg treated Jute/HDPE composite samples by using the Diamond TGA/DTA Perkin Elmer Model equipment. Thermal stability is evaluated at the heating rate of 10°C/min from the temperature 30 to 600°C under the flow of nitrogen. The initial mass loss of Alkali Jute/HDPE and oligomeric siloxan Jute/HDPE composite has occurred at temperature ranges of 270–390°C and 280–388°C respectively. The next stage of decomposition was taking place at the temperature range of 390–509°C. Poletto (2015) performed the TGA test on 10mg of treated Recycled polystyrene wood flour composite samples by using the equipment TGA Q50 under the flow of nitrogen at the heating rate of 10°C/min from the temperature of 25 to 600°C. At high temperature, the styrene-co-maleic anhydride (SMA) treated composite along with oligomers as coupling agents SMA2000 showed an increase in thermal stability by improving the adhesion between the wood flour and polymer matrix at the interface. This improvement was attained by the creation of intermolecular bonds.

From the detailed literature analysis, it is found that no researchers have reported the thermal properties of Phoenix sp. Fiber. Hence, in this work thermal analysis is carried out on the untreated and NaOH treated Phoenix sp. Fibers to determine its thermal behavior.

MATERIALS AND METHODS

Phoenix Sp. Fiber

The Phoenix sp. plants are widely available in the forests of Africa, China, Turkey, India, etc. It is growing in the region where there is high ground water level. Annually 0.5 tonnes of Fiber was acquired per acre. A plant contains 15 to 25 petioles of length 2.5 feet to 5 feet and the life of the plant is found around 20 years. The yield of the plant is 35 to 42 petioles per year Rajeshkumar et al. [2015, 2016].

Fiber Extraction



Figure 1: Extracted Phoenix sp. fiber

Fibers are extracted by a manual peeling process by using water retting process. At this time the gum-like substances are removed and then washed with distilled water in order to remove the unwanted substances. Then the Fibers are dried in the room temperature for 24 hours. Rajeshkumar et al. [2015, 2016]. Figure 1 shows the extracted Phoenix sp. Fiber.

Alkali Treatment

The extracted Phoenix sp. Fibers were soaked separately for about 1 hour at room temperature in the different concentrations 5%, 10% and 15% of NaOH solution. The alkali treatment on Phoenix sp. Fiber is shown in Figure 2. Then the treated Fibers were dried at room temperature for 48 hours after washing it with distilled water and running water to remove the NaOH solutions, residuals completely Boopathi et al. [2012].



Figure 2: Alkali Treated Phoenix sp. Fiber

PROPERTIES OF THE PHOENIX SP. FIBER

The properties of the Phoenix sp. Fiber are as follows

- Average diameter of the Fiber -577 μm
- Density of the Fiber - 1.2576 g/cc

- The cellulose, lignin, wax, ash, and moisture contents present in the Fiber are 76.13%, 4.29%, 0.32%, 19.69%, and 10.47% respectively.
- The maximum tensile strength and Young's modulus were around 348.95 MPa and 7.62 GPa respectively.

RESIN AND HARDENER

A commercial epoxy resin LY556 is mixed with its own amine-based hardener HY951 in the ratio of 9:1 by weight was used as a matrix. The densities are 1.15–1.20 g/cm³ and 0.97–0.99 g/cm³ for epoxy and hardener respectively Rajeshkumar et al. [2016].

TESTING

In order to evaluate the thermal properties of the Fiber, it was imposed for the following tests.

THERMOGRAVIMETRIC ANALYSIS

Thermogravimetric analysis (TGA) was carried out to define the thermal stability of untreated and alkali treated Phoenix sp. Fibers by using Perkin Elmer model TGA Q50 V20.13 Build 39 which is shown in Figure 3. Fiber samples of 1 - 10 mg were placed in an alumina pan and heated from 20 to 600:°C at a heating rate of 10:°C/min in the air atmosphere.

RESULTS AND DISCUSSIONS

Table 1 represents thermal degradation stages of untreated Phoenix sp. Fiber, untreated Phoenix sp. Fiber and the degradation stages of epoxy.

Table 1: Main Stages of Thermal Degradation

Fibre/ Resin	1st Stage of Degradation °C	2nd Stage of Degradation °C	3rd Stage of Degradation °C
Untreated	40-100	200-260	320-380
5% NaOH	220-280	320-360	400-450
10% NaOH	200-260	330-380	400-430
15 %NaOH	220-280	320-370	400-470
Epoxy	300-340	360-400	460-520

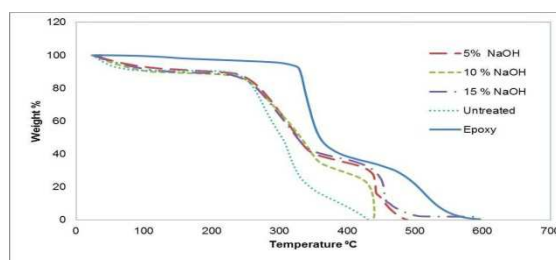


Figure 4: TGA Curve of Untreated and Treated Phoenix Sp. Fiber

For untreated Phoenix sp. Fiber, the first stage of thermal degradation has occurred between 40-100:°C due to the release of moisture content from the Fiber, between 200-260:°C the second stage of thermal degradation has occurred which was associated to the degradation of hemicelluloses and lignin of the Fiber, and the third stage of thermal degradation has occurred between the temperature range of 320-380:°C which was due to the degradation of α -cellulose from the Fiber. For 5% NaOH treated Phoenix sp. Fiber, the first stage of thermal degradation takes place between 220-280:°C which corresponds to the vaporization of absorbed moisture content during treatment, the second stage of

degradation which attributed to the degradation of hemicelluloses and lignin was noted between the temperature of 320-360:C and the last stage of degradation occurred due to degradation of α -cellulose is between 400-450:C .

For 10% NaOH treated Phoenix sp. Fiber, the initial stage of degradation happen between 200-260 Degree Celsius, which was attributed due to the elimination of moisture content from the Fiber, the next stage happened between 330-380 degree Celsius due to the decomposition of hemicelluloses and lignin and the final stage of degradation takes place between 400-430 degree Celsius which was related to the degradation of α -cellulose from the Fiber. For 15% NaOH treated Phoenix sp. Fiber, the first stage of degradation occurred between 220-280:C due to the removal of moisture content, the next stage of degradation takes place between 320- 370:C which indicates the decomposition of hemicelluloses and lignin and the last stage of degradation corresponds to the decomposition of α -cellulose occurred between 400-470:C For epoxy, the initial stage of degradation observed between the temperature 300-340:C which was associated due to the elimination of moisture content, the second stage of degradation occurred between 360-400:C due to the decomposition of hemicelluloses and lignin and the final stage of degradation takes place between 460-520:C which was related to the degradation of α -cellulose from the Fiber. From the Figure 4, it is clear that at 430:C the untreated Phoenix sp. Fiber degrades completely and then at 488:C the 5% NaOH treated Fiber gets degraded. For 10% NaOH treated Fiber, the Fiber gets degraded at 438:C, 98.3% of Fiber gets degraded at 596:C for 15% NaOH treated Fiber and the epoxy degrades at 596:C.

CONCLUSIONS

The first stage of degradation has occurred due to the release of moisture content from the Fiber. The major degradation occurred at the second stage, which was associated with the degradation of hemicelluloses and lignin of the Fiber. The last stage of degradation takes place due to the α -cellulose degradation of the Fiber. The degradation temperature of treated Fiber (320:C) was found to be higher than the untreated Fiber (200:C) which indicates the removal of waxy layers and the absence of hemicelluloses in the treated specimens. The chemically treated Phoenix sp. Fiber decomposed at a higher temperature (470:C) than untreated Fiber (380:C) indicating higher thermal stability for the treated Fiber. Thermal stability was found higher for 15% NaOH treated Fiber followed by 5 %NaOH treated Fiber, 10 % NaOH treated Fiber and untreated Fiber.

REFERENCES

1. Arrakhiz, F., et al., 2012. Mechanical and thermal properties of polypropylene reinforced with Alfa Fiber under different chemical treatment. *Materials & Design*, 35:318-322.
2. Arthanarieswaran, V., et al., 2016. Mechanical and thermal properties of Acacia leucophloeaFiber/epoxy composites: Influence of Fiber loading and alkali treatment. *International Journal of Polymer Analysis and Characterization*, 1-13.
3. Beall, F, C and H, W, Eickner., 1970. Thermal degradation of wood components: a review of the literature. DTIC Document.
4. Behera, D and A, Banthia., 2008. Synthesis, characterization, and kinetics study of thermal decomposition of epoxidized soybean oil acrylate. *Journal of applied polymer science*, 109(4): 2583-2590.
5. Boopathi, L., Sampath, P, S and Mysamy, K., 2012. Investigation of physical, chemical and mechanical properties of raw and alkali treated Borassus fruit Fiber. *Compos Part B*, 43: 3044–3052.
6. Geethamma, V., et al., 1998. Composite of short coir Fibers and natural rubber: effect of chemical modification, loading and orientation of Fiber. *Polymer*, 39(6): 1483-1491.

7. JA, Haameem, M., et al., 2016. Mechanical properties of Napier grass Fiber/polyester composites. *Composite Structures*, 136: 1-10.
8. Kabir, M., et al., 2010. Effect of chemical treatment on the mechanical and thermal properties of hemp Fiber reinforced thermoset sandwich composites. *Incorporating Sustainable Practice in Mechanics and Structures of Materials*, 439-444.
9. Lee, K.-Y., et al., 2012. Hierarchical composites reinforced with robust short sisal Fiber preforms utilising bacterial cellulose as binder. *Composites Science and Technology*, 72(13): 1479-1486.
10. Nishitani, Y., et al., 2016. Thermal properties of hemp Fiber filled polyamide
10. biomass composites and the blend of these composites and polyamide11 elastomer. *PROCEEDINGS OF PPS-31: The 31st International Conference of the Polymer Processing Society—Conference Papers*, AIP Publishing.
11. Paul, S.A., et al., 2008. Effect of Fiber loading and chemical treatments on thermophysical properties of banana Fiber/polypropylene commingled composite materials. *Composites Part A: Applied Science and Manufacturing*, 39(9): 1582-1588.
12. Poletto, M., 2015. Effects of the coupling agent structure on the adhesion of recycled polystyrene wood flour composites: Thermal degradation kinetics and thermodynamics parameters. *Journal of Composite Materials*, 0021998315618250.
13. Rajeshkumar, G., Hariharan, V and Sathishkumar, T, P., 2015. Characterization of Phoenix sp. natural Fiber as potential reinforcement of polymer composites. *Industrial textiles*, 1–17.
14. Rajeshkumar, G., Hariharan, V., Sathishkumar, T, P., Scalici, T., Fiore, V., 2016. Synergistic effect of Fiber content and length on mechanical and water absorption behaviours of Phoenix sp. Fiber-reinforced epoxy composites. *Industrial textiles*, 1–22.
15. Manickam.C, Christal.K, Prasanna S.C “Influence of particle size on the thermal conductivity of graphene composites” *Pakistan Journal of Biotechnology* Vol. 14 special issue Pp. 37- 39 (2017)
16. Ramzy, A., et al., 2014. Developing a new generation of sisal composite Fibers for use in industrial applications. *Composites Part B: Engineering*, 66: 287-298.
17. Vignesh.C ,Prasanna “Effect of constructional change in I.C engine piston by partially ceramic coating” *Pakistan Journal of Biotechnology* Vol. 14 special issue Pp. 116- 119 (2017)
18. Ticoalu, A., T, Aravinthan and F. Cardona., 2014. A study into the characteristics of gomuti (Arengapinnata) Fiber for usage as natural Fiber composites. *Journal of Reinforced Plastics and Composites*, 33(2): 179-192.